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A BREATHING EXERCISE WITH THE HUMANOID ROBOT NAO DESIGNED TO REDUCE STUDENT STRESS DURING CLASS: RESULTS FROM A PILOT STUDY WITH STUDENTS IN HIGHER EDUCATION

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Abstract

Breathing exercises are beneficial for human health on many levels including relaxation, stress and anxiety reduction. They can be used as an educational method in school and in higher education during breaks or before examinations for stress relief. Especially in times of the COVID pandemic, which has been shown to increase the psychological stress of students, ensuring students' well-being including stress reduction has become a highly relevant issue. However, breathing exercises are rarely applied, which may result from the lack of relevant knowledge, skills and/or experience of educators. Humanoid robots can be programmed to facilitate breathing exercises in educational contexts, for example, before or during classes, or before exams. This paper explores how the humanoid robot NAO was applied to guide breathing exercises with students in higher education. The paper presents the design and the programming of the application "Breathe and Relax with NAO", and the results from the pilot study with a small group of eight university students (75% female, 25% male). The application exploits the multimodal interaction possibilities of the NAO robot including speech, movements, sound and light effects. The results from the pilot study show that students enjoyed interacting with the robot, felt more relaxed after the exercise and reported that their mood improved compared to their emotional state before the exercise. Participants stated that the breathing exercise fulfilled their expectations and formulated some valuable recommendations for further development. The paper reports on these preliminary results and proposes further applications of the robot NAO as a facilitator of breathing exercises in education with the focus on students' well-being at times of crisis.

Keywords: humanoid robot, robot-assisted education, stress reduction, higher education, breathing exercises.

1 INTRODUCTION

Breathing exercises, especially slow, rhythmic breathing as part of "mindfulness" or "well-being" approaches, offer many health benefits including relaxation, improvements in sleep quality, and reduction of stress and anxiety. The psychological stress of students has become an important issue in education which was additionally exacerbated by the COVID pandemic and its containment measures. The pandemic and especially the isolation of students have been shown to increase stress-related indicators. In consequence, ensuring the well-being of students has become a relevant issue in education [1]. Well-being has been defined from multiple perspectives including well-being at the physiological level (associated with reduced stress) and at the emotional level (associated with a positive balance of positive and negative emotions) [2]. Well-being has been also conceptualised as a combination of hedonic well-being, comprising satisfaction, positive and negative effects, and eudaimonic well-being, comprising individual attributes such as autonomy, personal growth, positive relations with others and self-acceptance [3]. Studies which examined how hedonic and eudaimonic well-being are linked to mental and physical health provide some interesting evidence for the reciprocal relationship between well-being and health [3]. For example, studies showed that there is an overlap between hedonic well-being (e. g. perceived happiness) and self-rated health, as well as between eudaimonic well-being (e. g. personal growth, positive relations with others, and purpose in life) and lower levels of disrupted sleep. From this perspective, promoting well-being is important, especially in view of fostering mental and physical resilience in times of crisis [1].

Among many different approaches to promoting well-being, breathing exercises can be used for improving emotional well-being and reducing stress. For example, the study on the effects of meditation and breathing exercises on the well-being of patients with COVID infection showed that both meditation and breathing exercises had a statistically significant effect on reducing stress and improving the quality of sleep [4]. Furthermore, the same study showed that a 7-day program comprising a video-guided meditation and breathing exercises in the form of pranayama, which includes different methods of controlled breathing in Yoga, had positive effects on the level of anxiety of persons in isolation during the COVID pandemic [4]. Another, even shorter intervention in the form of a 4-day online breathing and meditation workshop during the COVID pandemic was tested with ninety-two healthcare providers, who reported significant improvements in life satisfaction, resilience, and the quality of sleep after the intervention [5]. The same study showed a significant reduction in the levels of stress, anxiety and depression immediately after the program [5]. Further work with athletes, showed that slow-paced breathing (SPB) has preventive and rehabilitative properties as it can activate anti-inflammatory pathways, and improve endurance, sports performance, emotional well-being, and sleep quality [6]. Studies on mindfulness-based stress reduction (MBSR) programs have shown similar effects. For example, a study with medical school students on an 8-week course of mindfulness compared this intervention to an 8-week general stress reduction course without mindfulness and showed that participants in the mindfulness course had significantly less burnout [7]. Another study showed that an 8-week mindfulness-based stress reduction program for educators had significantly contributed to the decrease of anxiety, fatigue, and emotional exhaustion [8].

Despite these and other promising results, stress reduction methods including breathing exercises and mindfulness-based stress reduction (MBSR) are still rarely applied in education, which may result from the lack of relevant knowledge, skills and/or experiences of educators. This poses a question of how digital media and technologies such as online courses, video and audio recordings, or humanoid robots can be applied in educational contexts to support stress reduction interventions. Compared to online courses, and video and audio recordings, humanoid robots offer embodied, multimodal interfaces which can be programmed to facilitate repeated breathing exercises in contexts which lack human educators capable of delivering such interventions. Previous studies have shown that human robots, such as the NAO robot, afford interactions similar to interactions with a human teacher and promote rapport-building, in the sense of mutual attentiveness, positivity, and coordination [9]. Since rapport is linked to effective communication, persuasion, liking, trust, and engagement [10], it is an important factor for learning and potentially for the effectiveness of anxiety and stress reduction programs [11].

This paper presents the exploratory design and programming of a simple breathing exercise with the humanoid robot NAO. The breathing exercise was programmed using the Choregraphe software and tested with a small group of eight students (75% female, 25% male) in the bachelor program in Digital Business during an on-campus seminar. The application developed for this purpose was called "Breathe and Relax with NAO" and was designed as an interactive exercise in which students follow the instructions of the NAO robot. The breathing exercise exploits the multimodal interaction possibilities with the NAO robot including speech, movements, sound and light effects in its interactions. The remainder of this paper describes the design, the programming and the evaluation results of the first version of the application.

2 METHODOLOGY

The application "Breathe and Relax with NAO" was designed using the Choregraphe software (Version 2.8.6). The implemented breathing exercise is called the 4-7-8 technique, in which the numbers 4-7-8 refer to counts of inspiration, holding the breath and expiration [12]. This technique has been used to help with anxiety and stress reduction. Studies have shown that it is effective in reducing anxiety and depression [12]. The 4-7-8 breathing technique uses the following breathing pattern: breath in through the nose for four seconds, hold the breath for seven seconds and breathe out through the mouth slowly for eight seconds. In the design of the application "Breathe and Relax with NAO", the humanoid robot NAO is taking the role of a facilitator, guiding participants by counting the seconds, moving its arms up and down, changing the color of the eyes and playing an introductory gong sound to mark the beginning of the main phases in the breathing exercise. The application consists of an introduction and preparation phase, as well as the exercise itself with a short interlude between two exercise cycles. The introduction phase consists of NAO introducing itself and the breathing exercise. After NAO explains the 4-7-8 breathing technique, participants are instructed to seat themselves comfortably but with a straight back, while NAO waits for a speech input from the participants who are asked to say whether they are ready to start the exercise. The first and second exercise phases consist of NAO counting the seconds, initiated by the gong sound. While NAO counts the first four seconds, it slowly lifts its arms and the LEDs in its eyes turn blue. The participants are asked to inhale through their noses. Once its arms reach the top, NAO counts for seven seconds and holds its arms in the air while its eyes turn yellow. At this stage, participants are asked to hold their breath for a few seconds. Concluding the cycle, NAO counts to eight and lowers its arms. Its eyes turn green, and the participants exhale through their mouths. The cycle is repeated multiple times with what is here called an interlude from NAO, reminding the participants where to focus their attention (e. g., how the air feels at the tip of their nose while inhaling). The flow diagram in Fig. 1 visualises the phases of the breathing exercise.

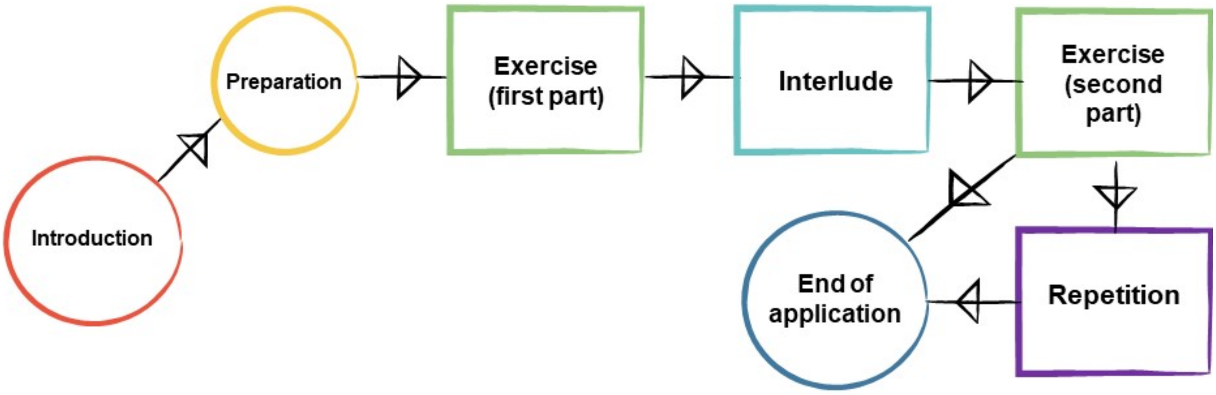

Figure 1. Flow diagram of the application “Breathe and Relax with NAO.”

In the newer version of the application, the interlude is placed after and before a set of four-cycle repetitions. This improvement was based on the feedback from participants who perceived the initial interruption as distracting. An option to repeat the exercise for another set is offered at the end of the exercise, which the participants can choose by pressing one of NAOs foot bumpers. Fig. 2 visualises the breathing exercise cycle in the software Choregraphe with its three layers of moving, speaking and changing the color of the eyes.

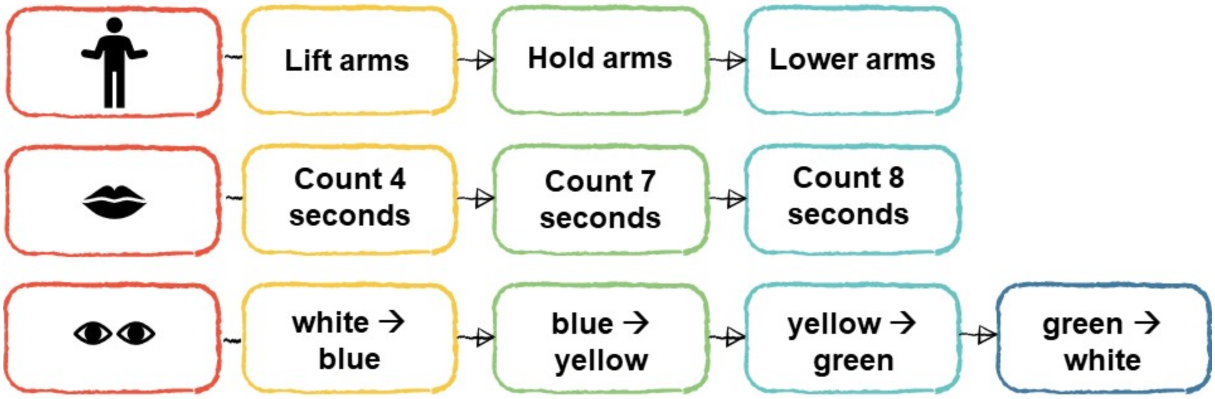

Figure 2. The layers of the application “Breathe and Relax with NAO” in Choregraphe.

3 RESULTS

The pilot study took place on campus, at Berlin University of Applied Sciences in June 2022, at the end of the summer semester 2022 in the Bachelor study program in Digital Business. The participation in the breathing exercise was voluntary. The key research questions were: *What are the expectations of students towards a humanoid robot facilitating a breathing exercise? How effective is a breathing exercise with the humanoid robot NAO for reducing self-perception of stress and improving self-perceived mood of students? How did students experience the breathing exercise with NAO and which improvements to the exercise would students recommend?* The following sections present the research instruments used in the study, the characteristics of the study sample and the results related to the research questions are listed above.

3.1 Research instruments

To collect the data to answer these research questions, an online survey was designed and filled in by participating students before and after the breathing exercise with NAO. The online survey included validated scales and self-designed items.

In order to explore the expectations of students towards NAO as a facilitator of the breathing exercise, students were asked to answer three questions about their expectations, i.e. two questions before the exercise and one question after the exercise. The two pre-exercise questions were: *What role do you expect NAO to play in the breathing exercise, what will the exercise look like? How do you expect the breathing exercise to affect you, , how will you feel after the exercise?* The post-exercise question was: *How well did the breathing exercise with NAO meet your expectations?* Additionally, students were asked about their general experience in breathing exercises: *How much experience do you already have with breathing exercises?*

In order to assess any possible changes in self-perceived stress levels and moods, the online survey applied two validated scales, i.e. the Perkhofer Stress Scale and the STAI-State Scale. The Perkhofer Stress Scale is a single-item scale which was validated in previous studies, e.g. the study by [13] showed significant correlations with the well-established and validated STAI-State Scale. The study could verify that the Perkhofer Stress Scale as a single-item scale can be used as a quick, simple, valid and reliable assessment tool for psychological stress. The Perkhofer Stress Scale was applied before and after the breathing exercise to compare self-assessment of stress in pre-post-conditions.

The STATI-State Scale is part of a larger State-Trait Anxiety Inventory (STAI) which is one of the most popular questionnaires used in anxiety and stress research [13]. The STAI Inventory is used to measure two types of anxiety, state and trait anxiety. While trait anxiety is understood to be a relatively stable inter-individual difference in the tendency to evaluate situations as threatening, state anxiety is a temporary mood characterised by tension, anxiety, nervousness and restlessness and is accompanied by increased activity of the autonomic nervous system [14]. The study presented in this paper used the short version of the STAI-State questionnaire with 10 items proposed by [14]. The 10-item STAI-State questionnaire was used to help participants in the study to reflect on their mood immediately after the specific situation of the breathing exercise and to ask how participants felt at that specific moment. The STAI-State items were assessed on a 6-point scale ranging from 1 = "not at all" to 6 = "very strong” to express the current mood of the participants.

In order to answer the question about how students experienced the breathing exercise with NAO and which improvements to the current version of the breathing exercise would students recommend, the online survey employed self-designed questions such as: *What did you like most about the breathing exercise with NAO? What did you not like about the breathing exercise with NAO? What would you recommend changing/improving in the next versions of the exercise? What is important for you in general when doing breathing exercises or meditation?*

Finally, the online survey included questions about the socio-demographics of students. The entire online survey comprised 15 questions and took about 10 minutes to fill in.

3.2 Participants

In total eight students filled in the online-survey before and after the breathing exercise. The sample comprised 75% female and 25% male participants. 87.5% of the participants were 20 to 24 years old and 12.5% 25 to 29 years old. 87.5% of the participants had little to no previous experience with breathing exercises (62.5% chose 3 on the scale from 1 = “no experience” to 6 = “very much experience”). On average, the value for the previous experience of participants with breathing exercises was 2.75 (SD = 1.28).

3.3 Results

The results from the online survey during the pilot study are described below in relation to each of the three key research questions. The IBM SPSS software was used for the statistical analysis.

3.3.1 Expectations of students towards the robot-led breathing exercise

The first research question was: *What are the expectations of students towards a humanoid robot facilitating a breathing exercise?* There were altogether three questions in the online survey related to this research question, two were asked before the breathing exercise (1-2) and one (3) after the exercise. These three questions were answered by the participants in the following way:

1. *What role do you expect NAO to play in the breathing exercise, what will the exercise look like?* Students expected NAO to act as a kind of meditation trainer providing instructions, keeping the time, leading the exercise, making breathing sounds while breathing in and out, using its voice to

guide through the exercise, counting, saying exhale and inhale, and possibly demonstrating some movements

2 *How do you expect the breathing exercise to affect you, how will you feel after the exercise?* The general response to this question was “relaxed”. 7 out of 8 participants (87.5%) stated that they expected to feel more *relaxed*, and one participant said they expected to feel *calmer*.

3 *How well did the breathing exercise with NAO meet your expectations?* Most participants stated that the breathing exercise met their expectations. For 87.5% of the participants, the breathing exercise with NAO met their expectations to a very high level (6 to 4 points on the scale from 1 = “not at all” to 6 = “fully”). The average rating was M = 4.63 (SD = 0.92).

3.3.2 Perception of stress and mood before and after the breathing exercise with NAO

The second research question was: How effective is the breathing exercise with the humanoid robot NAO in reducing self-perception of stress and improving the self-perceived mood of students? The results from Perkhofer Stress Scale used before and after the exercise and the STAI-State Scale show that students felt less stressed after the breathing exercise with the robot NAO. Table 1 summarises the results of the Perkhofer Stress Scale before and after the breathing exercise with NAO.

Table 1. Self-perception of stress before and after the breathing exercise with NAO assessed on the scale from 1 = no stress (“fully relaxed”) to 6 = fully stressed (“anxious”).

	Pre-exercise stress level	***Post-exercise stress level***
Mean	3.25	2.25
Std. Deviation	1.28	1.04

These results indicate that the level of perceived stress dropped by 1 point on the scale after the breathing exercise compared to the state before the exercise.

The STAI-State Scale was used to measure the mood after the breathing exercise and encompassed 10 semantic items for self-assessment of the current mood state. Four out of the 10 items on this scale are formulated in a positive way and are related to relaxation, i.e., calm, rested, confident and jolly, while six items are formulated in a negative way and are related to stress, i.e. tense, agitated, worried, nervous, uptight and anxious. The participants were asked to assess these 10 semantic items on a scale from 1 = "not at all" to 6 = "very strong”. Table 2 summarises the results after the breathing exercise by aggregating the results for positive items (relaxation) and negative items (stress).

Table 2. Self-perception of mood (state) by the participants after the breathing exercise with NAO assessed on the scale from 1 = "not at all" to 6 = "very strong”.

	Relaxed mood (4 items)	***Anxious mood (6 items)***
Mean	3.59	1.68
Std. Deviation	1.37	0.89

These results show that the items related to the relaxed mood received higher average ratings with a difference of approx. 2 points on the scale. In general, items related to anxious mood or stress received low values. The item with the highest value was “calm” with M = 4.13 (Min:1; Max:5), followed by “rested” M = 3.50 (Min:1; Max:5), “confident” M = 3.38 (Min:1; Max:5), and “jolly” M = 3.38 (Min:1; Max:6), which was the only item that received the highest value of “6”. This indicates that the quality of the mood improved not only in relation to relaxation but also to the jolly/merry aspect of the mood.

Additionally, as proposed by [14], the four positively formulated statements were recorded for evaluation as they reflect the general anxiety tendency in a negative expression. After recording the codes, all STATE statements were added to the total test score. The total score on the scale was M = 2.3 (Min:1.9; Max:3.0), which indicates that the general anxiety tendency was low, below 2.5 on the scale from 1 = "not at all" to 6 = "very strong”. The measured consistency of the scale was high with α=.816 (Cronbach’s Alpha), which is an indicator of good internal consistency of the STATI-Scale.

3.3.3 Expectations of students towards a humanoid robot facilitating a breathing exercise

The third research question was: *How did students experience the breathing exercise with NAO and which improvements to exercise would students recommend?* The answers from the online survey show that students enjoyed the breathing exercise with NAO and emphasised a number of elements which they really liked, such as animations, movements and gestures of the robot, detailed description of the exercise in the initial phase and the overall speed of the exercise and of speech of the robot, as well as the structure of the exercise. Students also named a few elements which they did not like, and these included the volume of joint movements which were louder than speech and the quality of the robotic voice, which was perceived as not very relaxing for some of the participants. The key recommendations for further development were to increase the volume of speech of the robot, to get rid of the pauses in speech between breaths, and to repeat the exercise more often, one after the other, without pauses in between, so that students could “really” feel the effect. The answers to the last question about general expectations towards breathing exercises and meditation included: a calm voice, silence, slow speech, calmness in the environment and a relaxing atmosphere.

4 CONCLUSIONS

This paper presented the design and programming of the application “Breathe & Relax with NAO” and the results from a pilot study with a small group of eight university students dedicated to the evaluation of a breathing exercise with the humanoid robot NAO. The results from the pilot study show that the expectations of participating students towards a robot-led breathing exercise were realistic and were met to a high degree. The breathing exercise with NAO applying the 4-7-8 technique proved to be effective for lowering the perceived level of stress and improving the perceived mood. Finally, the answers of the students revealed that the experience of a breathing exercise with the humanoid robot NAO was pleasurable and that students delivered a number of valuable recommendations for further development of the “Breathe & Relax with NAO” application. Further studies should explore the effects of breathing exercises with humanoid robots on the stress and relaxation of participants in different age groups in more detail. Ideally, future studies will have larger study samples and longer duration, possibly applying a longitudinal design in order to explore changes in stress and in mood over time.

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